**Introduction to Systems Thinking**

**Presenter:** Patrick Woessner, CIT, MICDS, St. Louis, MO USA

**Description**: How does climate change influence an ecosystem over time? Would Hamlet’s fate have changed if he’d killed Claudius earlier? How do oil prices respond to shocks in supply and demand? These questions can be explored through Systems Thinking, an approach to problem solving that examines how parts relate to the whole and may be used to study any kind of system: natural, scientific, engineered, human, or conceptual. In this session, learn how to use free software models to empower students to dynamically visualize, manipulate, and communicate how complex systems and ideas in science, economics, literature, sociology, and other disciplines really work.

Notes:

<http://bitly.com/systems_thinking_2012>

donella meadows books

components of a system, elements, interconnections, function

changes of function profoundly change the system, structure is the source of behavior,

thinking: construct mental model and simulate to draw conclusions and make decisions

see slide: habits of a system thinker

excerpts from Patrick Woessner’s presentation:

**Session Goals**

* Identify the three key components of all systems
* Understand the role of mental models in the thinking process
* Recognize the habits of systems thinkers
* Compare the basic building blocks of system models
* Use models/simulation to make predictions and draw conclusions
* Select strategies and resources for implementing systems thinking in your classroom

**What is Systems Thinking?**

Traditional analysis focuses on the individual pieces of what is being studied. Systems thinking focuses on how the things being studied interact with the other constituents of the system.

## What is a System?

Donella Meadows, author of [Thinking in Systems](http://www.amazon.com/Thinking-Systems-Donella-H-Meadows/dp/1603580557), defines a system as "A set of elements or parts that is coherently organized and interconnected in a pattern or structure that produces a characteristic set of behaviors, often classified as its “function” or “purpose.”  
  
Systems are typically comprised of three main components: **elements**, **interactions**, and **function**.   
  
**Elements** are typically the most obvious part of a dynamic system, but changing elements often has very little effect on the system.  
**Interactions** often involve the flow of information. Changing relationships usually changes system behavior.  
The **function** is typically the least obvious part of a dynamic system. A change in purpose changes a system profoundly.  
  
In general:

* A system is more than the sum of its parts.
* Many of the interconnections in systems operate through the flow of information.
* The least obvious part of the system, its function or purpose, is often the most crucial determinate of the system’s behavior.System structure is the source of system behavior. System behavior reveals itself as a series of events over time.

## Thinking and Mental Models

Barry Richmond, developer of the STELLA systems modeling software, describes thinking as "two activities: constructing mental models and then simulating them in order to draw conclusions and make decisions.” The idea that people rely on mental models can be traced back to Kenneth Craik’s suggestion in 1943 that the mind constructs "small-scale models" of reality that it uses to anticipate events.  
  
Mental models have been studied by cognitive scientists as part of efforts to understand how humans know, perceive, make decisions, and construct behavior in a variety of environments. More information regarding the theory of mental models can be found in Chapter 9 of [The Oxford Handbook of Thinking and Reasoning](http://www.amazon.com/Handbook-Thinking-Reasoning-Library-Psychology/dp/0199734682) by Keith J. Holyoak, Ph.D., Robert G. Morrison, Ph.D.

## Habits of a Systems Thinker

The Habits of a Systems Thinker, developed by the Waters Foundation, encompass a spectrum of thinking strategies that foster problem-solving and encourage questioning. Though “habit” is defined as a usual way of doing things, the Habits of a Systems Thinker do not suggest that systems thinkers are limited by routine ways of thinking. Rather, the Habits encourage flexible thinking and appreciation of new, emerging insights and multiple perspectives.

Assessing systems thinking habits can be challenging for teachers and students. The document below, created by the Catalina Foothills School District and Waters Foundation, includes rubrics for primary, intermediate, and secondary-level education.

## Models and Simulations

The following models and simulations have been compiled from a variety of sources and represent a broad range of disciplines, grade levels, and systems thinking skills. If you are new to models and simulations, begin with the embedded file below; it will walk you through a tour of the model that explains how it was built.

### Creative Learning Exchange Demo Dozen

This collection of [13 lessons and accompanying dynamic models](http://www.ciesd.org/influence/demo_dozen.shtml), is constructed with the STELLA® ([isee systems, Inc.](http://www.iseesystems.com/" \t "_blank)) modeling language. Demo Dozen is designed to support educators and students as they explore the pedagogic value of system dynamics in education. Equally relevant for those with no previous modeling experience and for experienced modelers alike, this array of models demonstrates the potential breadth of systems-based curriculum.

### Forio Simulate

[Searchable catalog of ~2500 models/simulations](http://forio.com/simulate/search/) (free and paid) that run via a Flash-enabled web browser.  
  
**Selected free Forio models/simulations**  
  
[Excellent Beverage and Beer Distributor](http://forio.com/simulate/jelson/excellentbeerdistrib/overview/)  
A variation on the MIT Beer Game. There are three scenarios to choose. The third scenario is the most realistic based on retail beer sellers' behavior when they have a high backlog of orders.  
  
[H1N1 Flu Outbreak](http://forio.com/simulate/netsim/h1n1/overview/)  
What is most effective in controlling the outbreak of the H1N1 flu virus in schools? Is it better to vaccinate or stay home? Use this learning lab to understand how infectious disease spreads and why H1N1 has been signaled a pandemic.  
  
[How Much Oil is Left?](http://forio.com/simulate/pontifexconsult/how-much-oil-is-left/run/)  
The British Petroleum oil well disaster is once again bringing the US’s (globe’s!) dependence on oil “to the surface”...as well as an important question. If we are forced to find and retrieve oil through risky (financially and environmentally) and expensive means - deep ocean drilling, converting tar sands - what does this say about how much oil (particularly “cheap oil”) remains?  
  
[Predator-Prey Dynamics](http://forio.com/simulate/netsim/predator-prey-dynamics/overview/)  
As the manager of a small but thriving natural wilderness area, would you allow a one-time harvest of a key species in the wilderness? What impact might it have on other populations? In this simple predator-prey system, experiment with different predator harvests, and observe the effects on both the predator and prey populations over time.  
  
[Technology Diffusion Simulator](http://forio.com/simulate/navigantsimulations/technology-diffusion-simulation/overview/)  
This simulator is a modified version of the classic Bass Diffusion Model (Bass 1969, Sterman 2000). It is intended to illustrate the dynamics of technology adoption, considering two driving forces for technology purchases -- marketing and "word-of-mouth.  
  
[Urban Dynamics](http://forio.com/simulate/mbean/urban-dynamics/overview/)  
Jay Forrester's classic Urban Dynamics model simulates the migration and movement of three socioeconomic classes in a city. It shows how the underemployed, labor, and the managerial-professional class have differing determinations of the attractiveness of a city.  
  
[LabU: Understanding Weight-Management](http://forio.com/simulate/tkabdelh/lab-u-forio/simulation/)  
Effective weight-management requires more than motivation. As with managing any complex system—and our body surely is one—it requires two essential skills: (1) Understanding and (2) Prediction. Lab U focuses on UNDERSTANDING… to help you better understand how the human energy and weight regulation system works, why it works that way, & how to better manage it.  
  
[Lemonade Stand](http://forio.com/simulate/benjamin/lemonade-stand/overview/)  
This is a simple economic model of the classic American lemonade stand. Users will be able to set prices for the lemonade, determine their daily (perishable) supply, and know what the next day's temperature will be.

### isee Systems

Free sample models for education made using isee Systems' STELLA software. NOTE: You will need the free [**isee Player**](http://www.iseesystems.com/softwares/player/iseeplayer.aspx) installed to run the models.  
  
**Life Science**  
[Amalgamated Industries](http://www.iseesystems.com/resources/Applications/STELLA/Amalgamated%20Industries.zip)  
Think through the consequences associated with the development of a widget plant upstream of the Alma Mater school. While the plant will be good for the region’s economy, will it release widgoxyn—a deadly chemical known to interfere with aquatic food webs—in such quantities that it will irreparably damage the stunningly beautiful Alma Mater Pond?  
  
[Mysteries of Easter Island](http://www.iseesystems.com/resources/Applications/STELLA/Easter%20Island.zip)  
Easter Island has long been viewed as deep in mysteries. Why does the island have so many statues? Why is the landscape so stark and forbidding? And why does the island support so few people? Conduct simulations to explore the effect of different birth rates on the long-term sustainability of the population and its island habitat.  
  
[Plant Succession](http://www.iseesystems.com/Resources/Applications/Stella/Plant%20Succession.zip)  
This model represents the progression that plants go through in a forest ecosystem, from forb to hardwood with each plant type readying soil conditions for the next type in the progression.  
  
[Natural Selection Pressure](http://www.iseesystems.com/Resources/Applications/Stella/Selective%20Pressure.zip)  
In this model, a rabbit population comes under a natural selective pressure from a fox population. The average speed of the rabbit population increases as a result. You can experiment with the strength of the natural selective force.  
  
[Simple Nitrogen Cycle](http://www.iseesystems.com/Resources/Applications/Stella/Simple%20Nitrogen%20Cycle.zip)  
This is a model of a basic nitrogen cycle, bringing the typical textbook diagrams to life by enabling students to play with the parameters which impact the cycle's dynamics.  
  
**Literature**  
[Virtual Hamlet](http://www.iseesystems.com/resources/Applications/STELLA/Virtual%20Hamlet.zip)  
This model, illustrates how STELLA can be used to create a virtual laboratory for exploring the plot and character development of a piece of literature. What would happen if Hamlet where a “man of actions” as opposed to a “man of thought?” How would different characterizations change both the timing and the overall ending of the play?  
  
**Mathematics**  
[The Balloon Problem](http://www.iseesystems.com/resources/Applications/STELLA/The%20Balloon%20Problem.zip)  
This model illustrates how a simple interface can facilitate experimentation with a mathematics model. The model depicts a classic problem in calculus known as the balloon problem. Experiment with different distances and velocities.  
  
[Distance and Time Problems](http://www.iseesystems.com/resources/Applications/STELLA/Distance%20&%20Time.zip)  
This model illustrates how a STELLA model interface can be used to facilitate hands-on experimentation with simple mathematics problems. Experiment with different constant rates of speed.  
  
[Non-Separable Differential Equations](http://www.iseesystems.com/resources/Applications/STELLA/Non-Separable%20Diff%20Eq%27ns.zip)  
Analytically daunting or deceptively simple? The model represents a classic problem—that of mixing hot and cold water in a bathtub. Experiment with different water temperatures and with different flow rates, showing the overall impact on the temperature of water in the tub.  
  
[President & Prime Minister](http://www.iseesystems.com/resources/Applications/STELLA/President%20and%20Prime%20Minister.zip)  
Whose coffee cools faster? This question quickly becomes relevant for the president and the prime minister as they travel together in a plane. Understand the cooling process. Then experiment with a cooling model.  
  
**Physical Sciences**  
[Pendulum Story](http://www.iseesystems.com/resources/Applications/STELLA/Pendulum%20Story.zip)  
Explore the concepts behind a simple pendulum. What effect, if any, do string length, initial displacement and bob mass have on a pendulum's motion? See how the variables of simple harmonic motion are related.  
  
[Temperature Control](http://www.iseesystems.com/resources/Applications/STELLA/P-I%20controller.zip)  
This model enables you to selectively turn on and off both “P” (proportional) and “I” (integral) controllers for a heat pump that seeks to maintain a constant temperature within a house.  
  
[Reversible Reactions](http://www.iseesystems.com/resources/Applications/STELLA/Reversible%20Reactions.zip)  
Storytelling is used to present the basic structure of a reversible chemical reaction. Experiment with different values for initial concentrations of product and reactant, as well as different rate constants for the forward and reverse reactions.  
  
[Virtual Bungee Jumping](http://www.iseesystems.com/resources/Applications/STELLA/Virtual%20Bungee.zip)  
Virtual bungee jumpers can experiment with different body weights and bungee cord strengths. Then they experiment with different platform heights and even different gravitational fields.  
  
[Michaelis-Menten Dynamics](http://www.iseesystems.com/Resources/Applications/Stella/Michaelis-Menten%20Dynamics.zip)  
The Michaelis-Menten equations are taught in virtually any unit on enzyme kinetics. The problem, for most students, is that the equations are abstract, and it's difficult for students to develop an intuitive sense for the processes the equations are being used to describe. This model provides a simple, physically-intuitive treatment of the enzyme kinetics phenomenon.  
  
[Pharmacokinetics](http://www.iseesystems.com/Resources/Applications/Stella/Pharmacokinetics.zip)  
In this illustration, you'll learn how STELLA can be use to move from mere memorization to a deeper understanding of pharmacokinetic processes. In the illustration, a simple interactive simulation lays the foundation for understanding the basic processes of drug-physiology interaction.  
  
**Social Sciences**  
[Extraverts and Introverts](http://www.iseesystems.com/resources/Applications/STELLA/ExtraIntro.zip)  
This map (not a running simulation model) uses STELLA’s storytelling feature to illuminate the differences between extraverts and introverts.  
  
[Immigration Dynamics](http://www.iseesystems.com/resources/Applications/STELLA/immigration.zip)  
Understand simplified representation of the immigration process—a process that has driven many waves of immigration over the course of US history. Then, test policies targeted at slowing the movement of immigrants from Mexico into the US, and the movement of industry from the US into Mexico.

### MIT Sloan Teaching Innovation Resources (MSTIR)

Free web-based simulations from the MIT Sloan School of Business  
  
[Salt Seller: A Commodity Pricing Simulation](https://mitsloan.mit.edu/MSTIR/system-dynamics/salt)  
In this live, web-based simulation, participants playing the role of salt producers seek to maximize their profits as they compete against one another in deciding how to price salt. This game simulates the salt industry as it is described in the [Ventures in Salt: Compass Minerals International](https://mitsloan.mit.edu/MSTIR/strategic-management/VenturesInSalt/) case study.  
  
[Eclipsing the Competition: The Solar PV Industry Simulation](https://mitsloan.mit.edu/MSTIR/system-dynamics/solar)  
In this live, web-based simulation, participants play the role of senior management at SunPower, a leading firm in the solar photovoltaic industry. The game simulates the solar PV industry as described in the [SunPower: Focused on the Future of Solar Power](https://mitsloan.mit.edu/MSTIR/sustainability/SunPower/) case study. Users compete against other firms, simulated by the computer, and set the industry conditions so as to learn about strategy under different conditions relating to learning, knowledge spillovers, and competitor behavior.  
  
[Fishbanks: A Renewable Resource Management Simulation](https://mitsloan.mit.edu/MSTIR/system-dynamics/fishbanks)  
In this multiplayer web-based simulation, participants play the role of fishers and seek to maximize their net worth as they compete against other players, deal with variations in fish stocks and their catch. Participants buy, sell and build ships, decide where to fish, and negotiate with one another. Policy options available to instructors include auctions of new boats, permits and quotas.  
  
[Platform Wars: Simulating the Battle for Video Game Supremacy](https://mitsloan.mit.edu/MSTIR/system-dynamics/platform-wars)  
In this live, web-based simulation, participants play the role of senior management of a video game hardware platform producer such as Sega, Nintendo, or Microsoft. Built around a companion [case study](https://mitsloan.mit.edu/MSTIR/system-dynamics/SonysBattle/) describing the launch of Sony’s PS3, participants learn about the dynamics of competition in multi-sided markets. In such markets success depends not only on a product’s price and features, but on how many people own it (a direct network externality) and on the number of games and applications available – that is, the size of the installed base of complementary products (an indirect network externality). Platform markets are increasingly common in settings besides video games, including computers, the Internet and e-commerce, mobile telecommunications, and many others.

## Recommended Readings: Articles

[System Dynamics and Learner-Centered Learning in Kindergarten through 12th Grade Education](http://www.clexchange.org/ftp/documents/whyk12sd/Y_1993-01SD&LearnerCentered.pdf)  
An argument for the necessity of change in the educational process and the applicability of system dynamics in K-12 education. By the founder of the discipline of system dynamics.  
  
[Systems Thinking, Four Key Questions](http://www.clexchange.org/ftp/documents/whyk12sd/Y_1993-05STFourKeyQuestions.pdf)   
A general overview of Systems Thinking. Interesting paper to read to get the perspective of a professional system dynamicist.  
  
[Bringing System Dynamics to a School Near You: Suggestions for Introducing and Sustaining System Dynamics in K-12 Education.](http://www.clexchange.org/ftp/documents/Implementation/IM2000-12BringSDToSchool.pdf)   
This paper explains how system dynamics is introduced and sustained in schools, outlining some of the many generous contributions that have made the early growth of K-12 system dynamics possible, and giving readers many resources and practical suggestions for how they can participate, too.  
  
[Consider The Gypsy Moth: An Example of System Dynamics for Carlisle](http://www.clexchange.org/ftp/documents/Implementation/IM1994-11ConsiderGypsyMoth.pdf)  
An explanation of how system dynamics would "look" and work in a curriculum, using the gypsy moth caterpillar as a concrete example of its application in a science curriculum. A simple presentation which clearly demonstrates how to start using and understanding basic system dynamics and modeling.  
  
[The Challenges of Infusing System Dynamics into a K-8 Curriculum](http://www.clexchange.org/ftp/documents/Implementation/IM2001-09InfusingSDIntoK-8.pdf)   
This paper describes the process of developing and implementing system dynamics lessons in the Carlisle, MA Public Schools. Using one lesson as an example, it will illustrate what the children do and what they learn. It also presents the problems of imbedding the lesson and the systems approach into the curriculum.

## Recommended Readings: Books

[Introduction to Systems Thinking with STELLA](http://www.amazon.com/An-Introduction-Systems-Thinking-STELLA/dp/0970492111/ref=sr_1_3?s=books&ie=UTF8&qid=1340126486&sr=1-3&keywords=systems+thinking+stella)  
This book is a guide to learning systems thinking and to using the STELLA software. It is published by isee systems, inc., in business for 26 years, dedicated to improving the way the world works by creating systems thinking-based products that enable people to increase their capacity to think, learn, communicate, and act more systemically. There are really two guides that teach an introduction to systems thinking. The STELLA guide is geared more toward educators and researchers.  
  
[Tracing Connections: Voices of Systems Thinkers](http://www.amazon.com/Tracing-Connections-Voices-Systems-Thinkers/dp/097049212X/ref=sr_1_1?s=books&ie=UTF8&qid=1340126760&sr=1-1&keywords=tracing+connections+voices+of+systems+thinkers)  
Shows how Systems Thinking can be used to transform education, business, public policy, and research. This book reveals how a new way of thinking can radically improve your ability to work through complex issues and uncover elegant solutions. It will leave you with a better understanding of what systems thinking is, who is using it, and why applying systems thinking is so important is this world of growing interdependence. Twelve of the world's foremost systems thinkers share how they use this powerful thinking tool to change lives.  
  
[Thinking in Systems: A Primer](http://www.amazon.com/Thinking-Systems-Donella-H-Meadows/dp/1603580557/ref=sr_1_1?s=books&ie=UTF8&qid=1340126788&sr=1-1&keywords=thinking+in+systems)  
Meadows' newly released manuscript, Thinking in Systems, is a concise and crucial book offering insight for problem solving on scales ranging from the personal to the global. Edited by the Sustainability Institute's Diana Wright, this essential primer brings systems thinking out of the realm of computers and equations and into the tangible world, showing readers how to develop the systems-thinking skills that thought leaders across the globe consider critical for 21st-century life.  
  
[The Shape of Change](http://www.iseesystems.com/store/college_university/shapeofchangebook.aspx)  
Presents eleven lessons to engage students in grades 3-8. Lessons incorporate games and other hands-on activities to help students observe and understand patterns of behavior and how things change over time. Students draw simple graphs and connection circles as they build their Systems Thinking skills.  
  
The Systems Thinking Playbook  
Linda Booth Sweeney and Dennis Meadows both have many years of experience in teaching complex concepts. This book reflects their insights. Every game works well and provokes a deep variety of new insights about paradigms, system boundaries, causal-loop diagrams, reference modes, and leverage points. Each of the thirty exercises here was tested and refined many times until it became a reliable source of learning. Some of the games are adapted from classics of the outdoor education field. Others are completely new. But all of them complement readings and lectures to help participants understand intuitively the principles of systems thinking.

## Recommended Readings: Modeling Software

[STELLA Modeling Software: isee systems](http://www.iseesystems.com/)  
isee systems is the world leader in Systems Thinking software. Founded in 1985 by Barry Richmond, then a Professor at Dartmouth College the company has grown into a thriving, privately-held corporation with substantial global reach in business, education, and government markets. Thousands of educators and researchers have made their STELLA software the gold standard; using it to study everything from economics to physics, literature to calculus, chemistry to public policy. K-12, college, and research communities have all recognized STELLA’s unique ability to stimulate learning.  
  
[Vensim Simulation Software](http://www.vensim.com/software.html)  
Vensim is used for developing, analyzing, and packaging high quality dynamic feedback models. Models are constructed graphically or in a text editor. Features include dynamic functions, subscripting (arrays), Monte Carlo sensitivity analysis, optimization, data handling, application interfaces, and much more. Ventana Systems also provides the [Molecules software](http://www.vensim.com/molecule.html), for constructing system dynamics models from "chunks" or molecules of system dynamics structure.  
  
[Insight Maker](http://insightmaker.com/)  
A web based modeling and simulation environment which provides for online development and simulation of stock & flow models. Because it is a web based environment it allows for easy sharing of models among a number of people with no worry as to whether everyone has the right software.

## Recommended Readings: Websites

[Creative Learning Exchange](http://www.clexchange.org/)  
The Creative Learning Exchange was founded as a non-profit in 1991 to encourage the development of systems citizens who use systems thinking and system dynamics to meet the interconnected challenges that face them at personal, community, and global levels. The Creative Learning Exchange encourages an active, learner-centered process of discovery for 5-19 year old students that engages in meaningful, real-world problem solving through the mastery of systems thinking and system dynamics modeling.  
  
[Pegasus Communications, Inc](http://www.pegasuscom.com/index.html)

##### Pegasus Communications helps organizations thrive in an increasingly complex world through the tools and principles of systems thinking and organizational learning.

Through a grounding in the rigorous principles and tools of systems thinking and related disciplines, practitioners from business, education, government, and the nonprofit world find the freedom to connect with others in new ways and design sustainable solutions to their most persistent challenges.  
  
[Waters Foundation: Systems Thinking in Schools](http://www.watersfoundation.org/index.cfm?fuseaction=home.main)  
The mission of the Waters Foundation is to increase the capacity of educators to deliver student academic and lifetime benefits through the effective application of systems thinking concepts, habits, and tools in classroom instruction and school improvement. Their K-12 Educational Partnership provides learning opportunities and resources for implementing system thinking principles.  
  
[CC Modeling Systems](http://www.ccmodelingsystems.com/index.html)  
CC Modeling Systems is a website dedicated to demonstrating the depth of understanding that can occur using system dynamics modeling with high school students. The web site features videos of students presenting their models as compelling evidence of the value of incorporating such modeling into the curriculum. Additionally, alignment of system dynamics modeling with the national educational standards in math, science, economics, health, sustainability, social studies, technology, and 21st Century Skills is presented. Training opportunities for teachers are also listed.  
  
[Systems Thinking World Wiki](http://www.systemswiki.org/index.php?title=Main_Page)  
Large collection of systems thinking-related resources, including webinars, videos, articles, models, and tutorials. Visitors new to systems thinking should begin with their  
[Learning References](http://www.systemswiki.org/index.php?title=Learning_Systems_Thinking) to support further development of key concept understanding.